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Specification and Drawings, as originally filed, with Application for Patent Serial No:
2,439,487, on September 4, 2003, by **OPTIMUM PRODUCTION TECHNOLOGIES
INC.**, assignee of Glenn Wilde, for "Positive Pressure Gas Jacket for a Natural Gas
Pipeline".

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POSITIVE PRESSURE GAS JACKET FOR A NATURAL GAS PIPELINE

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FIELD OF THE INVENTION

The present invention relates to methods and apparatus for protecting against the
10 influx of air into a pipeline carrying a combustible gas under negative pressure, and
particularly to such methods and apparatus for use in association with a pipeline carrying
natural gas under negative pressure from a natural gas well to a gas compressor.

BACKGROUND OF THE INVENTION

15

Natural gas is commonly found in subsurface geological formations such as deposits
of granular material (e.g., sand or gravel) or porous rock. Production of natural gas from
these types of formations typically involves drilling a well a desired depth into the formation,
installing a casing in the wellbore (to keep the well bore from sloughing and collapsing),
20 perforating the casing in the production zone (i.e., the portion of the well that penetrates the
gas-bearing formation) so that gas can flow into the casing, and installing a string of tubing
inside the casing down to the production zone. Gas can then be made to flow up to the
surface through a production chamber, which may be either the tubing or the annulus
between the tubing and the casing. The gas flowing up the production chamber is conveyed
25 through an intake pipeline running from the wellhead to the suction inlet of a wellhead

compressor. The compressed gas discharged from the compressor is then conveyed through another pipeline to a gas processing facility and sales facility as appropriate.

When natural gas is flowing up a well, formation liquids will tend to be entrained in the gas stream, in the form of small droplets. As long as the gas is flowing upward at or above a critical velocity (the value of which depends on various well-specific factors), the droplets will be lifted along with the gas to the wellhead. In this situation, the gas velocity provides the means for lifting the liquids, and the well is said to be producing by "velocity-induced flow". Because liquids in the gas stream can cause internal damage to most gas compressors, a gas-liquid separator is provided in the intake pipeline to remove liquids from the gas stream before entering the compressor. The liquids may be pumped from the separator and reintroduced into the gas flow at a point downstream of the compressor, for eventual separation at the gas processing facility. Much more commonly, however, the liquids are collected in a tank on the well site.

In order to optimize total volumes and rates of gas recovery from a gas reservoir, the bottomhole flowing pressure should be kept as low as possible. The theoretically ideal case would be to have a negative bottomhole flowing pressure so as to facilitate 100% gas recovery from the reservoir, resulting in a final reservoir pressure of zero. In order to reduce the bottomhole pressure to a negative value, or to a very low positive value, it would be necessary to have a negative flowing pressure (i.e., less than atmospheric pressure) in the intake pipeline. This can be readily accomplished using well-known technology; i.e., by providing a wellhead compressor of sufficient power.

However, negative pressure in a natural gas pipeline would present an inherent problem, because any leak in the line (e.g., at pipeline joints) would allow the entry of air into the pipeline, because air would naturally flow to the area of lower pressure. This would create a risk of explosion should the air/gas mixture be exposed to a source of ignition. In addition to the explosion risk, entry of air into the pipeline also creates or increases the risk of corrosion inside the pipeline. For these reasons, the pressure in the intake pipeline is typically maintained at a positive level (i.e., higher than atmospheric). Therefore, in the event of a leak in the intake pipeline, gas in the pipeline will escape into the atmosphere, rather than air entering the pipeline. The explosion and corrosion risks are thus minimized or eliminated, but in a way that effectively limits the rate at which gas can be produced from the well.

One way of minimizing or eliminating the explosion and corrosion risks, while facilitating the use of negative pressures in the intake pipeline, would be to provide an oxygen sensor in association with the pipeline. The oxygen sensor would be adapted to detect the presence of oxygen inside the pipeline, and to shut down the compressor immediately upon detection of oxygen. This system thus would more safely facilitate the use of high compressor suction pressures so as to induce negative pressures in the intake pipeline and, therefore, to induce negative or low positive bottomhole flowing pressures. However, this system has an inherent drawback in that its effectiveness would rely on the proper functioning of the oxygen sensor. If the sensor malfunctions, and if the malfunction is not detected and remedied in timely fashion, the risk of explosion and/or corrosion will become

manifest once again. This fact highlights an even more significant drawback in that this system would not prevent the influx of air into the pipeline in the first place, but is merely directed to mitigation in the event of that undesirable event.

5 For the foregoing reasons, there is a need for an improved method and apparatus for minimizing and protecting against the risk of explosion arising from the influx of air into a pipeline carrying a combustible gas such as natural gas under negative pressure. There is a particular need for such methods and apparatus that do not require or rely on the use of oxygen sensors or other instruments or devices that are prone to malfunction. Even more
10 particularly, there is a need for such methods and apparatus that prevent the influx of air into the pipeline in the first place. The present invention is directed to these needs.

BRIEF DESCRIPTION OF THE DRAWINGS

15 Embodiments of the invention will now be described with reference to the accompanying figures, in which numerical references denote like parts, and in which:

FIGURE 1 is a schematic diagram of a well producing natural gas in accordance with prior art methods and apparatus.

20 **FIGURE 2** is a schematic diagram of a well producing natural gas in accordance with a preferred embodiment of the method and apparatus of the present invention.

FIGURE 3 is a schematic diagram of a well producing natural gas in accordance with an alternative embodiment of the method and apparatus of the present invention.

BRIEF DESCRIPTION OF THE INVENTION

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In general terms, the present invention provides a method and apparatus whereby the intake pipeline running between the production chamber of a natural gas well and the suction inlet of an associated wellhead compressor is completely enclosed, in airtight fashion, within a jacket of natural gas under positive pressure (i.e., higher than atmospheric). Being enclosed
10 inside this "positive pressure jacket", the intake pipeline is not exposed to the atmosphere at any point. This allows gas to be drawn into the compressor through the intake pipeline under a negative pressure, without risk of air entering the intake pipeline should a leak occur in the pipeline. If such a leak occurs, there would merely be a harmless transfer of gas from the positive pressure jacket into the intake pipeline. If a leak occurs in the positive pressure
15 jacket, gas therefrom would escape into the atmosphere, and entry of air into the positive pressure jacket would be impossible.

The present invention will be best understood after first reviewing conventional methods and apparatus for carrying natural gas from a well to a compressor. **FIG. 1**
20 schematically illustrates a typical natural gas well **W** configured in accordance with prior art methods and apparatus. The well **W** penetrates a subsurface formation **F** containing natural gas (typically along with water and crude oil in some proportions). The well **W** is lined with a casing **20** which has a number of perforations conceptually illustrated by short lines **22**

within a production zone (generally corresponding to the portion of the well penetrating the formation F). As conceptually indicated by arrows 24, formation fluids including gas, oil, and water may flow into the well through the perforations 22. A string of tubing 30 extends inside the casing 20, terminating at a point within the production zone. The bottom end of the tubing 30 is open such that fluids in the wellbore may freely enter the tubing 30. An annulus 32 is formed between the tubing 30 and the casing 20.

It should be noted that, to facilitate illustration and understanding of the invention, the Figures are not drawn to scale. The diameter of the casing 20 is commonly in the range of 4.5 to 7 inches, and the diameter of the tubing 30 is commonly in the range of 2.375 to 3.5 inches, while the well W typically penetrates hundreds or thousands of feet into the ground. It should also be noted that except where indicated otherwise, the arrows in the Figures denote the direction of flow within various components of the apparatus.

In the well configuration shown in FIG. 1, the tubing 30 serves as the production chamber to carry gas from the well W, under positive pressure, to an above-ground intake pipeline 40 which in turn carries the gas through a gas-liquid separator 70 to the suction manifold 42S of a gas compressor 42. A downstream pipeline 44 connects at one end to the discharge manifold 42D of the compressor 42 and continues therefrom to a gas processing facility (not shown). As schematically indicated, liquids 72 separated from the gas flowing in the intake pipeline 40 will accumulate in a lower section of the separator 70. In the usual case, the liquids 72 flow from the separator 70 to a storage tank 80 on the wellsite.

The present invention may be best understood from reference to FIG. 2. The invention provides for production of gas under negative pressure, in which case the liquids 70 removed from the gas stream by the separator 70 will also be under negative pressure, and for this reason a vacuum pump 74 is provided as shown. The liquids 72 flow under negative
5 pressure through a pump inlet line 78 to the pump 74, which pumps the liquids 72, now under positive pressure, through a liquid return line 76 into the production pipeline 44 at a point Z downstream of the compressor 72. Alternatively, the liquids 72 may be pumped to an on-site storage tank 80.

10 As illustrated in FIG.2, the intake pipeline 40, the separator 70, and the pump inlet line 78 are fully enclosed by a vapour-tight positive pressure jacket 50 that defines a continuous internal chamber 52. The positive pressure jacket 50 will typically be constructed of welded steel. However, suitable and well-known alternative materials may be used without departing from the fundamental concept and scope of the present invention.

15 A gas recirculation pipeline 60 extends between, and is in fluid communication with, the downstream pipeline 44 (at point X located between the compressor 42 and point Y) and the intake pipeline 40 (at point Y located between the compressor 42 and the separator 70).

20 By means of the recirculation pipeline 60, a portion of the gas discharged from the discharge manifold 42D of the compressor 42 may be diverted into the positive pressure jacket 50, such that the intake pipeline 40, the separator 70, the pump 74, and the pump inlet line 78 are entirely enclosed by a "blanket" of gas under positive pressure. The positive

pressure jacket 50 thus enshrouds all components of the apparatus containing combustible fluids under negative pressure with a blanket of gas under positive pressure, thereby preventing the entry of air into the combustible fluids present in any of those components.

5 The embodiment shown in FIG. 2 provides for what may be termed a "static" positive pressure blanket, as the gas inside the positive pressure jacket 50 will be essentially stationary. In an alternative embodiment of the invention, illustrated in FIG. 3, the internal chamber 52 of the positive pressure jacket 50 is in fluid communication with the annulus 32 of the well W, such that gas from the internal chamber 52 of the positive pressure jacket 50
10 can be injected into the annulus 32. As shown schematically in FIG. 3, a pressure regulator valve 54 is provided to regulate the gas pressure inside the positive pressure jacket 50. The pressure regulator valve 54 may be set such that it will open, thus allowing gas to enter the annulus 32, only when the gas pressure in the internal chamber 52 of the positive pressure jacket 50 is above a selected value. Under either static conditions (as in FIG. 2) or gas
15 injection conditions (as in FIG. 3), internal chamber pressures in the approximate range of 40 to 50 pounds per square inch are considered desirable. However, higher or lower pressures may be used without departing from the concept and principles of the present invention.

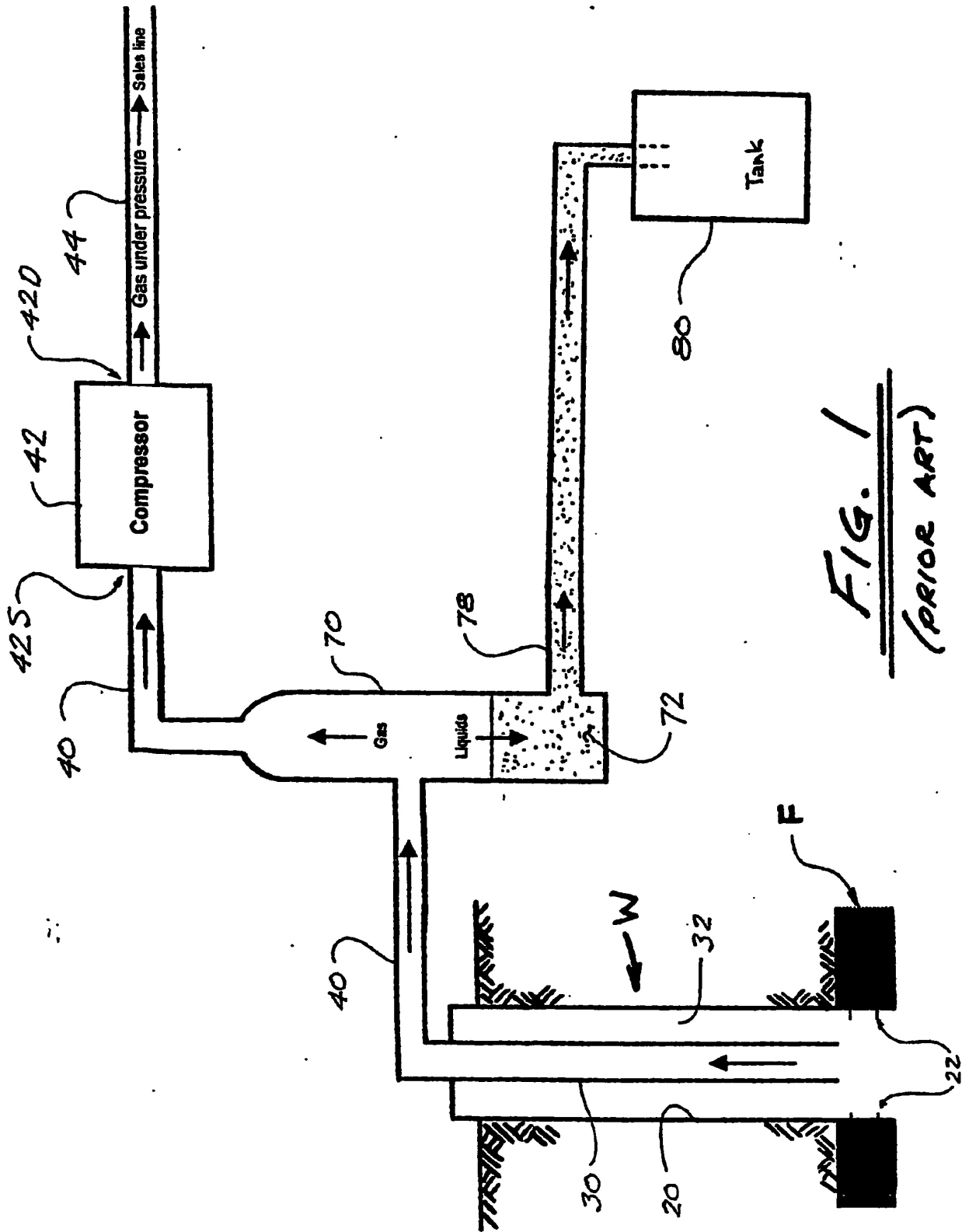
As schematically illustrated in FIG. 3, a throttling valve (or "choke") 62 optionally
20 may be provided in association with the recirculation pipeline 60, to regulate the flow of gas from the downstream production pipeline 44 into the recirculation pipeline 60 and thence into the internal chamber 52 of the positive pressure jacket 50 and ultimately into the well W.

Gas injection provides an additional benefit in that it enhances gas production from the formation F by further reducing bottomhole pressures in the well W. Formation pressures in virgin gas reservoirs tend to be relatively high. Therefore, upon initial completion of a well, the gas will commonly rise naturally to the surface provided that the characteristics of the reservoir and the wellbore are suitable to produce stable flow (meaning
5 that the gas velocity at all locations in the production chamber remains equal to or greater than the critical velocity – in other words, velocity-induced flow).

However, as wells penetrate the reservoir and gas reserves are removed, the formation
10 pressure drops continuously, inevitably to a level too low to induce gas velocities high enough to sustain stable flow. Therefore, all flowing gas wells producing from reservoirs with depleting formation pressure eventually become unstable. Once the gas velocity has become too low to lift liquids, the liquids accumulate in the wellbore, and the well is said to be "liquid loaded". This accumulation of liquids results in increased bottomhole flowing
15 pressures and reduced gas recoveries. Injection of recirculated gas, as provided for by the present invention, can be effective to prevent or alleviate liquid loading, by effectively increasing the upward velocity of the gas stream in the production chamber so as to maintain a gas velocity at or above the critical velocity for the well in question, thus maintaining velocity-induced flow. The effectiveness of gas injection for this purpose is described in
20 further detail in the present Applicant's Canadian Patent Application No. 2,242,745, filed on April 9, 2003.

Although not illustrated, it will be appreciated that the gas injection embodiment shown in FIG. 3 can be readily adapted for use in association with a gas well in which the annulus 32 serves as the production chamber. In that case, the intake pipeline 40 will be in fluid communication with the annulus 32, and the internal chamber 52 of the positive pressure jacket 50 will be in fluid communication with the bore of the production tubing 30. Accordingly, pressurized gas diverted into the internal chamber 52 will be injected into the well W through the tubing 30, with the same production-enhancing benefits as described previously in connection with embodiments wherein the tubing 30 serves as the production chamber.

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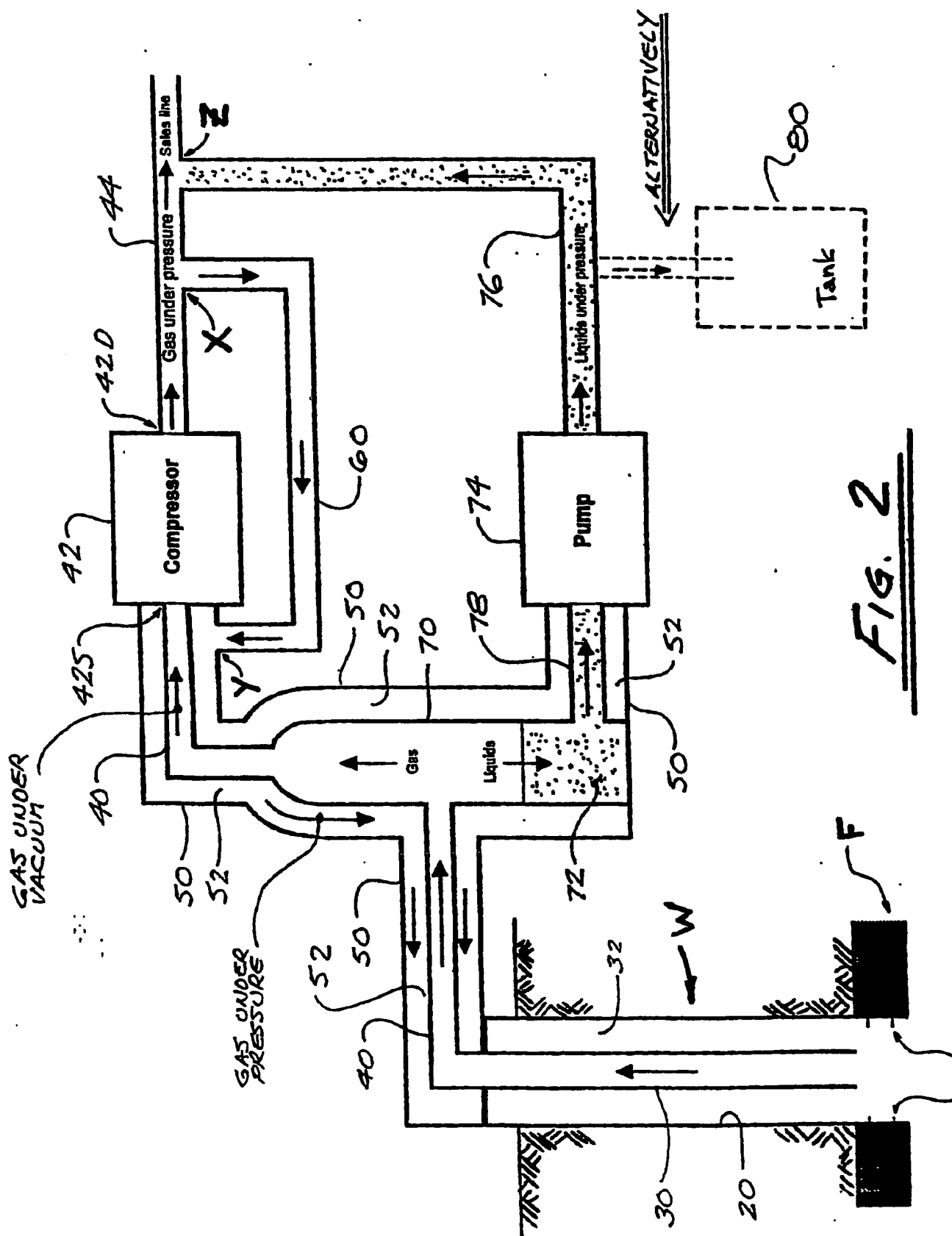


FIG. 2

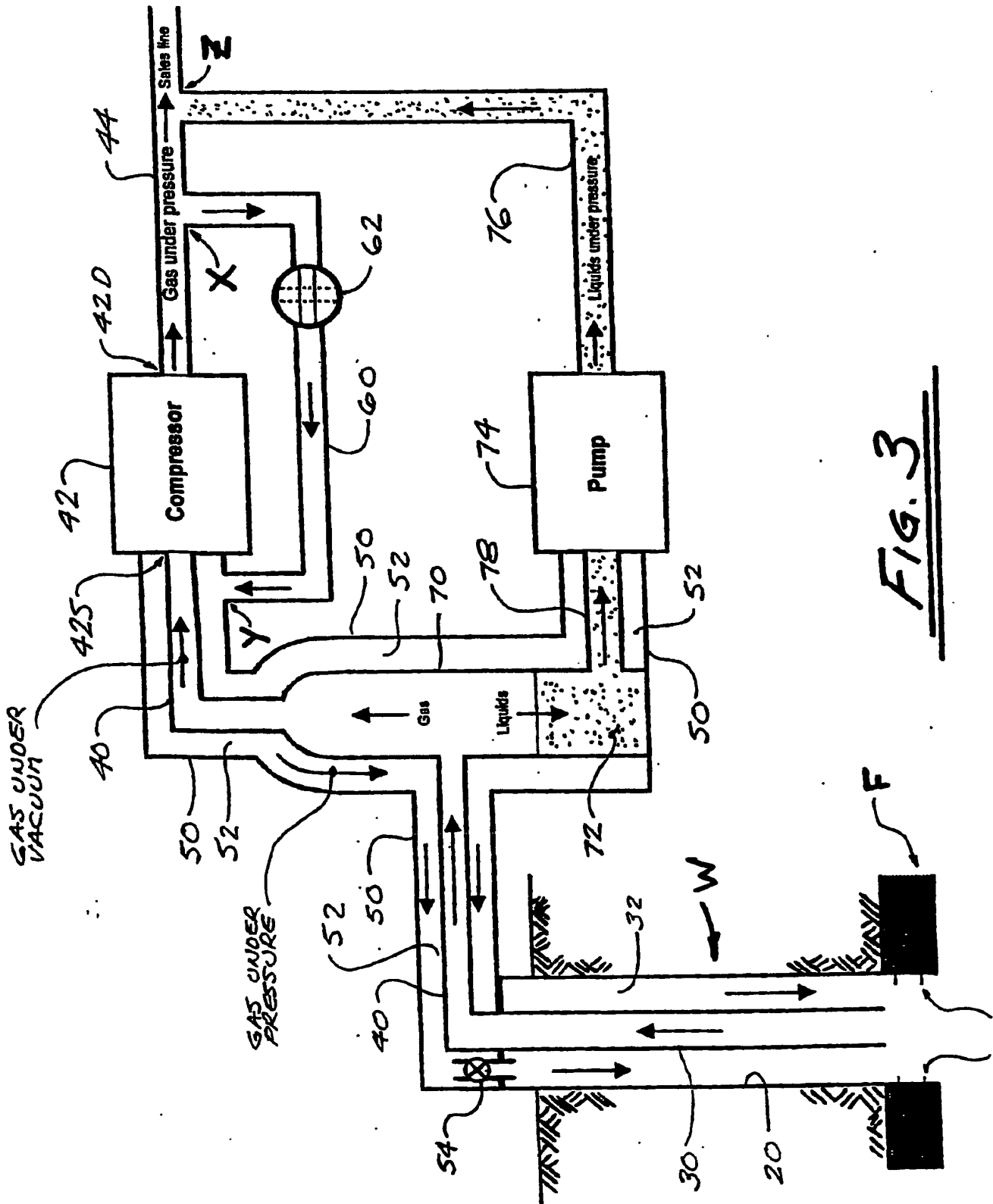


FIG. 3

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I hereby state that I have reviewed and understand the contents of the above-identified international application, including the claims of said application. I have identified in the request of said application, in compliance with PCT Rule 4.10, any claim to foreign priority, and I have identified below, under the heading "Prior Applications," by application number, country or Member of the World Trade Organization, day, month and year of filing, any application for a patent or inventor's certificate filed in a country other than the United States of America, including any PCT international application designating at least one country other than the United States of America, having a filing date before that of the application on which foreign priority is claimed.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Date: 13 August 2004

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